(12) UK Patent Application (19) GB (11) 2 086 931 A

(21) Application No 8127689
(22) Date of filing 11 Sep 1981
(30) Priority data
(31) 206240
(32) 12 Nov 1980
(33) United States of America (US)
(43) Application published 19 May 1982
(51) INT CL[3] C10J 3/00 C10K 1/06
(52) Domestic classification C5E 187 PC
(56) Documents cited
GB 2025453A
GB 1550636
GB 1499709
GB 1333979
(58) Field of search C5E

(71) Applicants
Texaco Development Corporation,
2000 Westchester Avenue, White Plains, New York, 10650, United States of America
(72) Inventors
Lawrence E. Estabrook,
Wolfgang Koog,
James Franklin Elliott,
George Neal Richter
(74) Agents
Michael Burnside & Partners,
2 Serjeants' Inn, Fleet Street, London EC4Y 1HL

(54) Ash removal and synthesis gas generation from coal

(57) The removal of ash formed by the gasification of an ash-containing fuel under superatmospheric pressure is facilitated by maintaining a flow of water from a quench zone where the ash particles are cooled to a lock hopper where the ash particles are collected and eventually discharged from the system.

SPECIFICATION

Ash removal and synthesis gas generation from coal

This invention relates to a process for the production of carbon monoxide and hydrogen i.e. synthesis gas from solid carbonaceous fuels by partial oxidation with an oxygen-containing gas and the removal of ash so produced. In one of its more specific aspects, it relates to the gasification of solid carbonaceous fuels at superatmospheric pressure in a non-catalytic flow type reactor in which a slurry of solid fuel in water in liquid phase is fed into a reaction zone maintained at an autogenous temperature in the range of about 1800 to 3200°F. and reacted therein with oxygen.

The generation of carbon monoxide and hydrogen or synthesis gas by non-catalytic reaction of solid carbonaceous fuel with air, oxygen-enriched air or relatively pure oxygen is disclosed in U.S. Patent 3,544,291 to W. G. Schlinger et al., the disclosure of which is incorporated herein by reference. Partial oxidation of solid fuels such as coal or petroleum coke represents a highly economical method for the production of synthesis gas in large quantities. In the flow-type gasifier or partial oxidation reactor, solid fuel is reacted with an oxygen-containing gas in a closed compact reaction zone in the absence of packing at an autogenous temperature within the range of about 1800 to 3200°F. preferably at a temperature in the range of 2000 to 2800°F.

Ordinarily, in the gasification of fuels such as coal or coke, the fuel in finely divided form is subjected to partial oxidation with the production of a product gas containing carbon monoxide and hydrogen and also containing minor amounts of carbon dioxide and methane and if the feed contains sulfur, hydrogen sulfide and carbonyl sulfide. However, since insufficient oxygen is introduced into the gasification zone for the complete combustion of the carbon in the fuel, that is, for the conversion of all of the carbon in the fuel to carbon dioxide, some of the solid fuel will proceed through the gasification zone without being converted to an oxide of carbon. In addition, when the feed to the gasification zone contains ash, particles of ash will also appear in the product gas.

Usually, it is desirable to remove these solid particles from the product gas. For example, if the sensible heat of the gas is to be recovered by indirect heat exchange, it may be advisable to remove the solid particles from the gas prior to introducing it into a heat exchanger to prevent their collecting on the walls or heat transfer surfaces of the heat exchanger with subsequent interference with the flow of fluids therethrough and the transfer of heat. One method of doing this is to impinge the hot particles on the surface of water in a quench zone to quench and wet them thereby removing them from the gas stream and transferring them to the water. In another method, if the product gas is to be used for the production of hydrogen, the gas ordinarily is quenched by being introduced into water under the surface thereof in a quench zone with the solid particles being retained in the water and the substantially particle-free gas saturated with water is then subjected to catalytic shift conversion. A combination of such techniques is disclosed in U.S. Patent 3,998,609 to W. B. Crouch et al., the disclosure of which is incorporated herein by reference. To prevent the build-up of solids and/or impurities in the quench water, periodically or continuously a portion of the quench water is removed and to maintain a constant liquid level in the quench zone, is replaced by water, preferably clarified water recycled from a settling zone to which the removed portion is sent.

When the gasifier is being operated at elevated pressure, the solid particles must be removed for the system without breaking the pressure and this may be done by introducing the particles into a lock hopper and then releasing them from the system. Since the operation of the lock hopper is controlled by valves, the inlet to the lock hopper is generally of a relatively small diameter compared to the gasifier apparatus which means that there is a section of downwardly decreasing cross-sectional area immediately above the lock hopper.

Unfortunately, there are occasions when material balances show that for the amount of feed to the gasifier and the amount of gas produced, there is a deficiency in the amount of solid particles being removed through the lock hopper. When this condition persists for a prolonged period of time, it becomes necessary to shut down the operation and remove the blockage which usually occurs at the constricted section of the apparatus above the upper lock hopper valve.

An advantage of the present invention is that it makes it possible to produce a substantially particle free gas comprising carbon monoxide and hydrogen. Another advantage is that the invention makes it possible to produce synthesis gas under superatmospheric pressure. Still another advantage is that the invention makes it possible to enhance the removal of ash and unconverted solid fuel particles from a system for the gasification of ash containing fuels.

According to the invention, there is provided a process for the production of substantially particle-free synthesis gas which comprises subjecting an ash-containing fuel to partial oxidation under superatmospheric pressure to produce a stream of synthesis gas comprising carbon monoxide and hydrogen and containing hot particles of ash and unconverted fuel, quenching the hot particles by contacting them with water in a quench zone, allowing the particles to settle through said quench zone into a water-filled collection zone and maintaining a flow of water containing quenched particles from said quench zone to said collection zone.

The feed to the process of our invention comprises any ash-containing carbonaceous fuel such as coal, sub-bituminous coal, lignite, some types of coke, biomass and the like. Ordinarily,

such fuel is solid, although fuels which are liquid at elevated temperatures such as coal liquefaction residue may also be used. To be considered ash-containing, the fuel should have an ash content of at least about 1 weight percent. If the feed is molten at elevated temperature, it may be preheated and introduced into the gasification zone as a liquid. If, however, the fuel is solid even at elevated temperatures, then it should be ground to a particle size of less than 1/4 inch and preferably ground so that at least 95% passes through a U.S. standard 14 mesh sieve (1.41 mm opening). The fuel is then injected into the gas generation zone where it is subjected to partial oxidation with a gas such as air, oxygen-enriched air, or substantially pure oxygen, that is, oxygen having a purity of at least about 95%. The solid fuel may be introduced into the partial oxidation zone as a slurry in a liquid such as water or oil or as a suspension in a gaseous or vaporous medium such as steam, carbon dioxide or mixtures thereof. Water or steam may also be introduced into the gasification or partial oxidation zone as a temperature moderator when the fuel feed is liquid or a slurry of solids in oil or other combustible liquid.

In the gas generation zone, the fuel is subjected to partial oxidation at an autogenously maintained temperature between about 1800 and 3200°F., preferably between about 2000°F. and 2800°F. The pressure in the gas generation zone may range between about 40 and 3000 psig preferably between about 60 and 2500 psig. The oxygen may be introduced into the gasification zone at an oxygen-to-carbon atomic ratio of between about 0.7 and 1.6 preferably between 0.8 and 1.2. If the fuel is solid and is introduced into the gasification zone as a slurry in water, the slurry should contain less than about 50 weight percent water, as a water content above that amount will affect the thermal efficiency of the reaction.

In one method of recovering heat from synthesis gas produced by the partial oxidation of an ash-containing fuel, the gas may be passed downwardly from the gas generator through a radiation cooling zone together with the entrained particles of ash and any unconverted fuel particles present. The gas is then diverted from its original path through the radiation cooling zone and, in a preferred embodiment, in a more or less upwardly direction to a convection cooling zone where it is passed upwardly in indirect heat exchange with a cooling medium such as water. The solid particles continue on their path and come into contact with water in a quench zone at the base of the radiation cooling zone where they are wetted and tend to settle in the water. The solid particles then pass downwardly through the upper valve of a lock hopper which also may be considered a settling zone where they collect. Since the upper valve of the lock hopper is maintained for the most part in an open position, the lock hopper is filled with water. Periodically, to discharge the solid particles, the upper valve of the lock hopper is closed and a valve situated at the base of the lock hopper is opened allowing the water and solid particles to be drained from the system. When this has been completed, the lower valve of the lock hopper is closed, the lock hopper is filled with water, pressurized, and then the upper valve is opened to permit additional ash or slag to settle and be collected in the lock hopper. Alternatively and preferably as a corrosion-preventing measure, the lock hopper is maintained full of water while the collected solids are being discharged. This is effected by introducing water preferably at the top of the lock hopper, while the upper valve between the lock hopper and the quench chamber is closed, through a separate inlet at the same rate as the contents of the lock hopper are discharged through the opened lower valve. In this way, the lock hopper is constantly full of water and air is not permitted to enter the lock hopper.

To prevent the formation of a blockage above the upper valve of the lock hopper in one embodiment of the invention, water is circulated externally from the lock hopper to the quench zone to cause a downward flow of water containing entrained particles through the upper lock hopper valve. This may be accomplished by withdrawing water from the top or near the top of the lock hopper and returning it directly or indirectly to the quench zone. By a modification of valves and piping, the opening used for the withdrawal of water for return to the quench zone may be the same opening used for the introduction of water during the lock hopper discharge cycle. Advantageously, the outlet for the withdrawn water is separated from the downflowing stream of water containing quenched particles by a baffle so that a minimum of particles is returned to the quench zone. By operating in this manner, a continuous stream of water passes downwardly from the quench zone to the collection zone assisting in the transfer of the solid material from the quench zone to the collection zone or lock hopper and thereby preventing the formation of a blockage. However, this stream is stopped when the lock hopper cycle for the removal of the collected solid particles is initiated.

The rate of flow of water from the quench zone to the collection zone or lock hopper is not critical but should exceed the rate of upflow, that is the rate of upward flow of water displaced by the descending ash particles if there were no circulation. As a practical matter, the downflow rate should be at least 0.03 feet per second preferably at least 0.05 feet per second.

Since the inlet and the outlet of the lock hopper are controlled by valves, the connection between the outlet of the quench zone and the inlet to the lock hopper has a section of gradually decreasing cross-sectional area. To prevent larger particles of ash or slag plugging this area or plugging the valve, it is advisable to have a grinder above the constricted section.

After the synthesis gas has left the convection section it may be put to any suitable use such as for the synthesis of organic compounds, the production of hydrogen or for use as a fuel.

Although the radiation cooler has been described as downflow and the convection cooler as upflow, it is possible with modifications in the apparatus to have the gas flow in either direction through each piece of equipment.

In another method of heat recovery, the oxygen containing gas and fuel are introduced into the generator or partial oxidation zone at the top thereof and passed downwardly through the generator. A water containing quench zone is located at the base of the generator but before reaching the quench zone the hot product gas is diverted in a more or less upward direction into a radiation cooling zone while the solid particles continue on their path into the quench water where they are wetted and sink through the water in the quench zone into a lock hopper or collecting zone. The diverted gas may then be passed in one case upwardly through a radiation cooling zone and then down through a convection zone or in another case, down through a radiation cooling zone and upwardly through a convection cooling zone or alternatively either upwardly or downwardly through both cooling zones.

Again, to assist in the movement of solid particles from the quench zone to the collection zone, water is circulated from the collection zone to the quench zone to provide a constant downward flow stream from the quench zone through the upper lock hopper valve to the collection zone.

Water circulated externally from the collection zone may be introduced into the quench zone above the surface of the water container therein and sprayed on the surface, thus serving to wet any floating particles causing them to sink or, on the other hand, it may be introduced below the surface of the quench water and directed upwardly towards the surface to increase the turbulence in the quench zone or directed downwardly thus increasing the force of the water flow to the lock hopper and reducing the tendency of slag or ash particles to form a bridge across the narrower section of the entry into the lock hopper with the resulting blockage of flow of solids into the lock hopper or any combination of the three. When the circulating water is introduced under the surface of the quench water in an upward direction, there is produced a flotation effect which tends to separate the particles rich in carbon from the more dense particles rich in ash, then advantageously, the quench blowdown is taken from near the surface of the quench water to remove water having a higher proportion of carbon-rich particles. The quench blowdown stream is a stream removed from the quench zone to help reduce the amount of contaminants, such as chlorides and formates in the quench water. A supply of water is introduced into the quench zone to replace that withdrawn in the quench blowdown thereby to maintain the water level in the quench zone substantially constant.

In another embodiment of the invention, rather than circulate water from the lock hopper to the quench chamber, water may be withdrawn from the lock hopper and combined with the quench blowdown stream and transferred to a settler where the solid particles settle from the water which may then be returned to the quench zone as makeup quench water or used for the preparation of additional slurry feed. To compensate for the increased flow of water to the settler, the flow of makeup quench water into the quench zone is increased in an amount equal to the amount drawn off from the lock hopper. In this way, a flow of water from the quench chamber through the upper lock hopper valve into the lock hopper is maintained.

Exemplary of the efficacy of our invention is to be seen in a series of high pressure coal gasification runs in which the feed to the gasifier was a Kentucky No. 9 coal. All of the runs were made under substantially identical operating conditions. The first run lasted 26.6 hours when the operation had to be shut down because of bridging of the slag above the upper lock hopper valve. After removal of the bridge, gasification was resumed but bridging with slag resulted in the second run being shut down after 18 hours. The third run lasted 20.5 hours and the fourth run almost 20 hours when each had to be shut down for the same reasons. Prior to the fifth run, a blowdown system was installed to take off water from the top of the lock hopper into the quench blowdown at a steady rate. The downward flow of water from the quench chamber through the upper lock hopper valve into the lock hopper at a rate of 0.07 feet per second was successful in that the fifth run continued for 42.5 hours and was terminated not by plugging with slag but for mechanical reasons. When this condition was corrected, the unit was started up and ran successfully for 66.8 consecutive hours when the run was voluntarily terminated. Subsequently, the unit was run for 112 consecutive hours.

It is apparent from the foregoing runs that prior to the installation of the invention it was necessary to shut down the unit after about 20 to 25 hours of operation because of plugging. However, after the installation of a system whereby water could be flowed from the quench chamber through the upper lock hopper valve and into the lock hopper there was no plugging or bridging of slag in the equipment and over 200 hours of operation were completed without encountering this problem.

While the invention has been described with respect to gasification systems where the synthesis gas is introduced into the quench water under the surface thereof so that not only the solid particles of ash and unconverted fuel are quenched but also the synthesis gas itself is quenched, it works equally well in gasification operations in which the water in the quench zone is in a more or less quiescent state.

Various modifications of the invention as herein before set forth may be made without departing from the spirit and scope thereof, and therefore, only such limitations should be made as are indicated in the appended claims.

CLAIMS

1. A process for the production of substantially particle-free synthesis gas which comprises subjecting an ash-containing fuel to partial oxidation under superatmospheric pressure to produce a stream of synthesis gas comprising carbon monoxide and hydrogen and containing hot particles of ash and unconverted fuel, quenching the hot particles by contacting them with water in a quench zone, allowing the quenched particles to settle through said quench zone into a water-filled collection zone and maintaining a flow of water containing quenched particles from said quench zone to said collection zone.

2. A process according to Claim 1 in which said flow is maintained by circulating water from said collection zone to said quench zone.

3. A process according to Claim 2 in which the circulating water is introduced into the quench zone above the surface of water contained therein.

4. A process according to Claim 2 in which the circulating water is introduced into the quench zone below the surface of water contained therein.

5. A process according to any one of Claims 1 to 4 in which the gases and entrained particles leaving the partial oxidation zone pass through a radiation cooling zone before the particles reach the quench zone.

6. A process according to any one of Claims 1 to 4 in which the gases are diverted to a radiation cooling zone while the particles continue on their path into water in a quench zone.

7. A process according to Claim 5 or Claim 6 in which the gas path through said radiation cooling zone is downward.

8. A process according to Claim 5 or Claim 6 in which the gas path through said radiation cooling zone is upward.

9. A process according to any one of Claims 1 to 8 in which the collection zone is kept full of water while the particles are being removed therefrom.

10. A process according to Claim 1 in which water withdrawn from the collection zone is combined with a blowdown stream taken from the quench zone, the mixture so formed is permitted to settle, and water recovered from the settling zone is returned to the system.

11. A process according to Claim 10 in which the settled water is returned to the quench zone.

12. A process according to Claim 10 in which the settled water is introduced into the partial oxidation zone with the ash-containing feed.

13. A process for the production of substantially particle-free synthesis gas as claimed in Claim 1 and substantially as hereinbefore described.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1982. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.